Research Article

IJCRR
Section: General Science
Sci. Journal
Impact Factor 4.016
ICV: 71.54

# Forest Invasive Species Assessment Study in Different Village Forests of Garhwal Himalaya

**Arti Khanduri[1], Sas Biswas[2], H.B. Vasistha[3]**

[1]Doon(PG) College of Agriculture Science and Technology, Camp Road, Selaqui, Dehradun-248006; [2]Professor, Department of Forestry, Dolphin PGI, Dehradun-248001; [3]Formerly Scientist-F, Department of Ecology, Forest Research Institute, Dehradun-248001

## ABSTRACT

Forest invasive species (FIS) are exotic/alien species that occur outside their natural adapted ranges and dispersal potential. Some of the alien species become invasive, when they are introduced deliberately or unintentionally outside their natural habitats into new areas, where they express the capability to establish, invade and outcompete native species. The present study is focuses over the encroachment of invasive species in the two different forest communities of the Tehri Garhwal region of Western Himalaya. Data was collected through extensive field survey and quadrat method. High invasion was recorded in the shrub and herb layer of the forest. In tree strata native species are dominant but their recruitment in the form of sapling and seedlings are displaced by the dense thickets of invasives in both the communities. A highest value of ecological indices was evaluated in *Pinus roxburghii* dominated site as compared to the *Quercus leucotrichophora* dominated site. *Lantana camara, Eupatorium glandulosum, Clematis gouriana, Rosa brunonii, Rubus neivus, Euphorbia royleana* etc. are the most destructive Forest Invasive Species (FIS*) of both the forest communities. The present study gives an accurate assessment and understanding of the dynamics of invasives, which is further important for their scientific management and utilization.

**Key Words:** Western Himalaya, Biological invasion, Invasive species, Plant community, Dominance

## INTRODUCTION

India is one of the 17 mega biodiversity countries of the world. Diverse geographical and edaphic conditions of the country provide the luxuriant growth for various kind of flora and fauna (Chaudhry, *et.al.,* 2011). This diverse ecological condition provides platform for different new (alien) species to come up. Being rich in ecological diversity, forest ecosystem of the Himalayan region gives high value of ecosystem services. Its diversified landforms, relief and climatic zones support a wide range of vegetations. (Rana *et.al.,* 2010). In last century, the ecology of the Himalayan region has changed to a considerable level. Increase in the overall temperature of earth atmosphere and especially Himalayan region has changed the rainfall as well as seasons. Damming of rivers in Himalayan region has changed the ecology of the adjacent areas to lacusterine from riverine, resulting in change in flora of the region (Adhikari *et. al.,* 2009). This climatic as well as ecological change is also responsible for encroachment of the region by new (alien) species. According to the Convention on Biological Diversity, invasive alien species are the second largest cause of biodiversity loss in the world and impose high costs to agriculture, forestry, and aquatic ecosystems (Raizada *et.al.,*2008). The global extent and rapid increase in invasive species is homogenising the world's flora and fauna (Mooney and Hobbs, 2000) and is recognized as a primary cause of global biodiversity loss. Bio-invasion may be considered as a form of biological pollution and significant component on global change and one of the major causes of species extinction (Mooney and Drake, 1987).

Persistent colonies composed of invasive woody perennials alter the structure and function of forest ecosystems by inhibiting the growth and development of native species (Webster *et al.,* 2006). The ability of these species to inhibit the recruitment of native species raise the possibility that large-scale invasions may fundamentally change the successional

**Corresponding Author:**
**Arti Khanduri,** Doon(PG) College of Agriculture Science and Technology, Camp Road, Selaqui, Dehradun-248006
Email: khanduriarti@gmail.com

**ISSN:** 2231-2196 (Print) **ISSN:** 0975-5241 (Online) **DOI:** 10.7324/IJCRR.2017.9172
**Received:** 03.08.2017 **Revised:** 15.08.2017 **Accepted:** 27.08.2017

trajectory of forest ecosystems. Such a change would have far-reaching implications for numerous plant and animal species that rely on native plant communities and their successional pathway (Webster *et. al.,* 2006).

Forest invasive species are thus a serious hindrance to conservation and sustainable use of biodiversity with significant undesirable impacts on the goods and services provided by ecosystems. It is reported that losses due to alien invasive species in the country amounts to about US$130 billion annually. Forest alien species is now at global scale and it is expected that it will undergo rapid increase due to interaction with other changes such as globalization of markets, rise in global trade, travel and tourism (McNeely, *et.al.,*2001).

Our lack of knowledge about how invasive species function in their new environment significantly undermines our ability to detect and eradicate new or small infestations, therefore the effective management of invasive species, is only possible by gathering knowledge about their ecology, morphology, phenology, reproductive biology, physiology and phytochemisty , so that we can find and eliminate new infestations.

## MATERIAL AND METHODS

### Study area

The State of Uttarakhand lies between $28^0 44'$ to $31^0 28'$ N latitude and $77^0 35'$ to $81^0 05'$ E longitude, encompasses an area of 53,483 $Km^2$. The Garhwal Himalaya encompasses all 4 of the Himalayan physiographic-geological zones. These are broadly classified into Shiwalik, Lesser Himalaya, great Himalaya and Trans Himalaya.

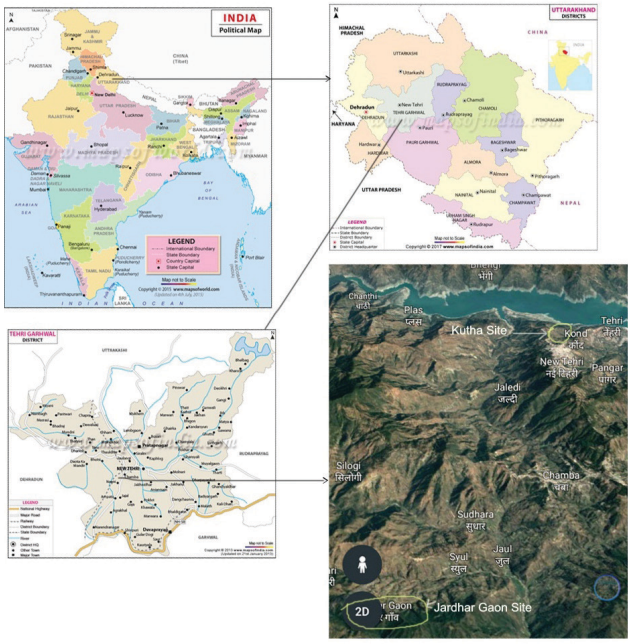


**Figure 1:** Study Area Location Map of Jardhar Gaon Site and Kutha Site

The study was carried out in the District Tehri Garhwal of Uttarakhand, which lies between $30^0 1'$ to $30^0 9'$ N latitude and $77^0 9'$ to $79^0 1'$ E longitude in Garhwal Himalaya and covers an area of 3796 sq. km of area. The region is highly mountainous, ranging from 300-7000m in altitude. The sites selected for the study were Jardhar village forest ecosystem and Kuttha village forest ecosystem. Both the areas selected for study are part of the lesser Himalayan ranges. Both are situated on north-eastern aspect, thus, received almost same amount of insolation. The two study sites have different altitude level and ecology. The Jardhar Village study area lies between the altitudinal range of 1400 mtr to 1800 mtr, whereas, the Kutha Village study site lies between 1000 to 1400 mtr altitude. Apart from altitudinal variation in sites, there is one more important feature of Kutha Village site i.e, it is part of the peripheral slope of Tehri Dam Reservior.

### Phytosociological assessment

To assess the extent of invasives in the forest area, a vegetation/phytosociological study was carried out. The vegetational surveys were conducted in the pre-monsoon and post monsoon periods of the study year. Detailed field surveys were adopted for recording the floristic composition of the communities in these sites.

The vegetation sampling was carried out, in order to reveal the quantitative impact in terms of IVI value, occurrence and area of occupancy of FIS in different sites.

Quadrat method was used to sample the vegetation. Size of quadrats used during the study were, 10m x10m, 5m x 5m, and 1m x 1m (Mishra, 1968), to enumerate trees, shrubs and herbaceous plants respectively. In Site I (Jardhar village forest) 120 quadrats were laid whereas in Site II (Kuttha village forest) 50 quadrats were found sufficient.

Individuals between 10.5 to 31.5cm cbh (circumference at breast height i.e., 1.37m above ground level) were recorded as shrubs and individuals less than 10.5cm cbh were considered as herbaceous plant (Knight, 1963).

The seedlings were considered as herbs and saplings as shrubs. Elevation/altitude, longitude, latitude of the site was recorded by GPS at 5-6 accuracy.

The Phytosociological data were quantitatively analysed for frequency, density and abundance following Curtis and McIntos (1950) and Mishra (1968). Importance Value Index (IVI) was determined as the sum of the relative values of frequency, density and dominance. The relative values of these parameters Relative frequency (RF), Relative density (RD) and Relative dominance (RDom)) were determined following Phillips (1959). Abundance (A)/ frequency (F) ratio, (Whitford, 1949) was used to interpret the distribution of the species. The distribution was classified viz.,-regular (<0.25), random (0.025-0.05) and contagious (>0.05) following the method of Curtis and Cottam (1956).

## FREQUENCY, DENSITY AND ABUNDANCE

Frequency refers to the degree of dispersion of individual species in an area and is usually expressed in terms of percentage occurrence. It can be calculated as:

$$\text{Frequency \% (F \%)} = \frac{\text{No. of quadrats of occurrence of a species}}{\text{Total no. of quadrats studied}} \times 100$$

$$\text{Density (D)} = \frac{\text{Total no. of individuals of a species in all the quadrats}}{\text{Total no. of quadrats studied}}$$

$$\text{Abundance (A)} = \frac{\text{Total no. of individuals of a species in all the quadrats}}{\text{Total no. of quadrats in which species occurred}}$$

$$\text{Relative frequency (RF)} = \frac{\text{No. of occurrence of the species}}{\text{No. of occurrence of all species}} \times 100$$

$$\text{Relative density (RD)} = \frac{\text{No. of individuals of the species}}{\text{No. of individuals of all species}} \times 100$$

Basal Area: This is regarded as an Index of dominance of a species. Higher the basal area, greater is the dominance and this is calculated by the term of relative dominance.

$$\text{Rel. Dom (RDom)} = \frac{\text{Total basal area of the species in all quadrats}}{\text{Total basal area of all species in all the quadrats}} \times 100$$

A total picture of the ecological status of a species with respect to a particular community structure can be obtained only after calculating the values of RF, RD, RDom. These values when added together given the importance value index (IVI).

IVI= Rel.frequency +Rel.density +Rel.Dominance

## RESULTS

The most important constituents of vegetation are plant species and their assemblages, which depend on various factors such as altitude, aspect, soil, geology, topography, natural herbivores and anthropogenic activities (Mueller-Dombois and Ellenberg, 1974). The functioning of an ecosystem is determined by the components of a community. They vary in quality and quantity in a given time and space, and has impact on the structure of the community. Therefore structure and composition of the vegetation reflect the ecosystem properties and ecological conditions of an area and form the basis for further scientific and management studies (Lindenmayer and Franklin, 1997). This paper deals with the ecological status of the sites in terms of plant structure, composition and invasion level along the native species in the affected village forests.

## ECOLOGICAL STATUS OF SITE I (JARDHAR VILLAGE FOREST ECOSYSTEM)

**Tree layer:** A total of fifty six tree species were recorded in the site. Out of these, 55 species were broad leaf and one species, i.e., *Pinus roxburghii* was conifer. The most dominant tree species of the forest was *Quercus leucotrichophora* followed by *Rhododendron arboreum* and *Pinus roxburghii* .While, in terms of invasion only one tree species *Euphorbia royleana* was reported as invasive. The species was distributed randomly along with native species of the area. (Fig 2 & Table 1)

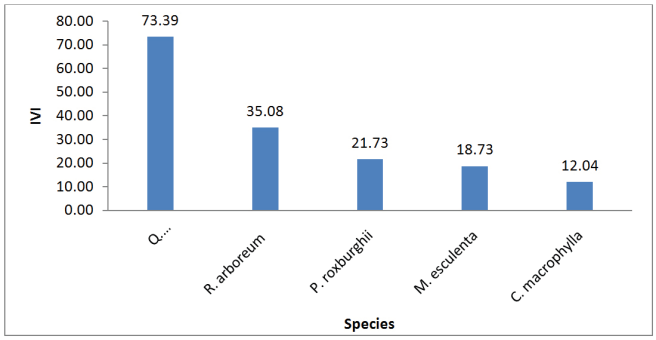


**Figure 2:** Dominant tree species of site I (Jardhar VFE)

**Table 1: Vegetation composition of tree layer of site I (Jardhar VFE)**

| S. No. | Species | Den/ha | TBA($m^2$/ha) | IVI | A/F |
|---|---|---|---|---|---|
| 1 | *Quercus leucotrichophora* | 457.69 | 17.47 | 73.39 | 0.05 |
| 2 | *Rhododendron arboreum* | 242.31 | 6.88 | 35.08 | 0.04 |
| 3 | *Pinus roxburghii* | 136.54 | 4.68 | 21.73 | 0.07 |
| 4 | *Myrica esculenta* | 115.38 | 3.67 | 18.73 | 0.05 |
| 5 | *Cornus macrophylla* | 57.69 | 1.84 | 12.04 | 0.02 |
| 6 | *Lyonia ovalifolia* | 102.88 | 0.77 | 11.36 | 0.03 |
| 7 | *Prunus cerasoides* | 71.15 | 0.34 | 9.59 | 0.02 |
| 8 | *Viburnum mullaha* | 76.92 | 0.34 | 8.28 | 0.03 |
| 9 | *Pyrus pashia* | 55.77 | 0.12 | 6.76 | 0.02 |
| 10 | *Viburnum cotinifolium* | 57.69 | 0.23 | 6.35 | 0.04 |
| 11 | *Lonicera caucasica* | 33.65 | 0.09 | 4.49 | 0.03 |
| 12 | *Pyracantha crenulata* | 34.62 | 0.03 | 4.41 | 0.03 |
| 13 | *Rhus wallichii* | 33.65 | 0.10 | 4.14 | 0.04 |
| 14 | *Bauhinia semla* | 27.88 | 0.41 | 4.12 | 0.06 |
| 15 | *Sapium insigne* | 32.69 | 0.10 | 4.09 | 0.04 |
| 16 | *Engelhardtia colebrookiana* | 33.65 | 0.08 | 4.08 | 0.04 |
| 17 | *Cocculus laurifolius* | 35.58 | 0.07 | 3.83 | 0.06 |
| 18 | *Lonicera quinquelocularis* | 28.85 | 0.05 | 3.79 | 0.03 |

| | | | | | |
|---|---|---|---|---|---|
| 19 | *Ficus arnottiana* | 30.77 | 0.07 | 3.62 | 0.05 |
| 20 | *Woodfordia fruticosa* | 24.04 | 0.05 | 3.18 | 0.04 |
| 21 | *Litsea glutinosa* | 27.88 | 0.06 | 2.92 | 0.08 |
| 22 | *Cornus capitata* | 21.15 | 0.14 | 2.67 | 0.08 |
| 23 | *Euphorbia royleana** | 30.77 | 0.07 | 2.44 | 0.28 |
| 24 | *Punica granatum* | 19.23 | 0.06 | 2.36 | 0.07 |
| 25 | *Sageretia oppositifolia* | 17.31 | 0.04 | 2.30 | 0.06 |
| 26 | *Prunus armeniaca* | 11.54 | 0.32 | 2.29 | 0.09 |
| 27 | *Erythrina suberosa* | 25.00 | 0.09 | 2.24 | 0.22 |
| 28 | *Bauhinia vahlii* | 18.27 | 0.01 | 2.12 | 0.08 |
| 29 | *Olea glandulifera* | 14.42 | 0.07 | 2.01 | 0.07 |
| 30 | *Bauhinia variegata* | 15.38 | 0.05 | 1.99 | 0.07 |
| 31 | *Rhus parviflora* | 14.42 | 0.02 | 1.89 | 0.07 |
| 32 | *Terminalia tomentosa* | 14.42 | 0.02 | 1.89 | 0.07 |
| 33 | *Acer oblongum* | 14.42 | 0.08 | 1.80 | 0.11 |
| 34 | *Lannea coromandelica* | 19.23 | 0.04 | 1.77 | 0.21 |
| 35 | *Ougeinia oojeinensi* | 15.38 | 0.05 | 1.76 | 0.12 |
| 36 | *Albizia lebbeck* | 20.19 | 0.02 | 1.76 | 0.22 |
| 37 | *Cotoneaster bacillaris* | 15.38 | 0.04 | 1.73 | 0.12 |
| 38 | *Pistacia integerrima* | 13.46 | 0.05 | 1.69 | 0.10 |
| 39 | *Coriaria nepalensis* | 11.54 | 0.08 | 1.66 | 0.09 |
| 40 | *Plumeria rubra* | 15.38 | 0.08 | 1.52 | 0.26 |
| 41 | *Morus serrata* | 11.54 | 0.02 | 1.50 | 0.09 |
| 42 | *Embelia robusta* | 13.46 | 0.03 | 1.46 | 0.15 |
| 43 | *Juglans regia* | 11.54 | 0.01 | 1.33 | 0.12 |
| 44 | *Ficus nemoralis* | 14.42 | 0.01 | 1.32 | 0.24 |
| 45 | *Pyrus communis* | 10.58 | 0.06 | 1.26 | 0.18 |
| 46 | *Indigofera pulchella* | 9.62 | 0.01 | 1.25 | 0.10 |
| 47 | *Berberis asiatica* | 9.62 | 0.02 | 1.18 | 0.13 |
| 48 | *Melia azadarach* | 7.69 | 0.08 | 1.18 | 0.13 |
| 49 | *Debregeasia velutina* | 9.62 | 0.02 | 0.95 | 0.29 |
| 50 | *Rhus cotinus* | 8.65 | 0.02 | 0.91 | 0.26 |
| 51 | *Grewia optiva* | 5.77 | 0.03 | 0.81 | 0.17 |
| 52 | *Emblica officinalis* | 7.69 | 0.02 | 0.70 | 0.52 |
| 53 | *Ficus palmata* | 5.77 | 0.01 | 0.61 | 0.39 |
| 54 | *Acacia catechu* | 5.77 | 0.01 | 0.61 | 0.39 |
| 55 | *Toona ciliata* | 3.85 | 0.01 | 0.52 | 0.26 |
| 56 | *Dalbergia sissoo* | 3.85 | 0.01 | 0.50 | 0.26 |

## Forest Invasive Species*

**Shrub layer:** A total number of 72 species were recorded under shrub layer. Out of them 39 species were shrubs and 33 species of trees in the form of saplings. The most dominant species under this category was *Lantana camara* followed by *Rubus ellipticus* and *Myrisine africana* (Fig 3, Table 2).

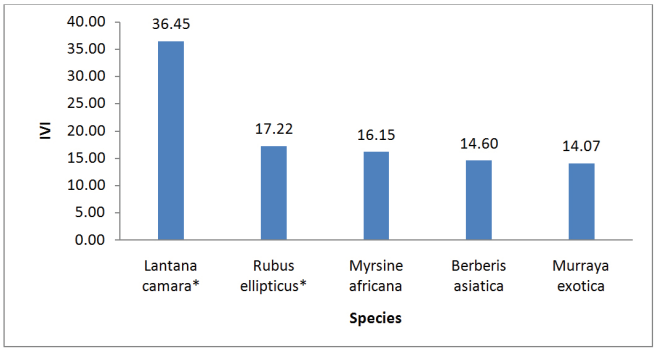


**Figure 3:** Dominant shrub species of site I (Jardhar VFE)

## Invasion status of shrub layer:

Shrub layer was encroached by total a no. of 11 invasive species. The most dominating invasive species were *Lantana camara* followed by *Rubus ellipticus* and *Rosa brunonii*. (Fig. 3 & Table 2).

**Table 2: Vegetation composition of shrub layer of site I (Jardhar VFE)**

| S. No. | Shrub species | Den/ha | TBA ($m^2$/ha) | IVI | A/F |
|---|---|---|---|---|---|
| 1 | *Myrsine africana* | 433.33 | 0.67 | 16.15 | 0.02 |
| 2 | *Berberis asiatica* | 333.33 | 0.99 | 14.60 | 0.03 |
| 3 | *Murraya exotica* | 316.67 | 1.05 | 14.07 | 0.04 |
| 4 | *Uraria lagopus* | 316.67 | 0.56 | 12.13 | 0.03 |
| 5 | *Tephrosia candida* | 270.00 | 0.70 | 11.50 | 0.03 |
| 6 | *Asparagus* sp. | 180.00 | 0.56 | 8.97 | 0.03 |
| 7 | *Berberis lyceum* | 233.33 | 0.05 | 7.27 | 0.03 |
| 8 | *Desmodium elegans* | 176.67 | 0.04 | 5.58 | 0.04 |
| 9 | *Zanthoxylum armatum* | 116.67 | 0.18 | 4.95 | 0.04 |
| 10 | *Woodfordia fruticosa* | 93.33 | 0.29 | 4.05 | 0.12 |

| | | | | | |
|---|---|---|---|---|---|
| 11 | *Cryptolepis buchanani* | 86.67 | 0.13 | 3.74 | 0.05 |
| 12 | *Adhatoda vasica* | 56.67 | 0.23 | 3.04 | 0.10 |
| 13 | *Carissa opaca* | 60.00 | 0.23 | 2.84 | 0.18 |
| 14 | *Leptodermis kumaonensis* | 60.00 | 0.16 | 2.55 | 0.15 |
| 15 | *Murraya koenigii* | 60.00 | 0.04 | 1.85 | 0.18 |
| 16 | *Indigofera* sp. | 43.33 | 0.10 | 1.84 | 0.16 |
| 17 | *Asparagus adscendens* | 36.67 | 0.11 | 1.76 | 0.16 |
| 18 | *Flacourtia ramontchi* | 33.33 | 0.13 | 1.65 | 0.24 |
| 19 | *Agave cantula* | 30.00 | 0.10 | 1.45 | 0.22 |
| 20 | *Colebrookia oppositifolia* | 23.33 | 0.12 | 1.24 | 0.53 |
| 21 | *Desmodium cephalotes* | 16.67 | 0.08 | 0.86 | 0.67 |
| 22 | *Roylea calycina* | 16.67 | 0.06 | 0.78 | 0.67 |
| 23 | *Artemisia nilagarica* var. *septentrionalis* | 16.67 | 0.06 | 0.78 | 0.67 |
| 24 | *Wikstroemia canescens* | 13.33 | 0.06 | 0.74 | 0.53 |
| 25 | *Caryopteris foetida* | 13.33 | 0.07 | 0.70 | 1.20 |
| 26 | *Indigofera gerardiana* | 16.67 | 0.04 | 0.68 | 0.67 |
| 27 | *Cajanus volubilis* | 13.33 | 0.04 | 0.63 | 0.53 |
| 28 | *Solanum anguivi* | 10.00 | 0.05 | 0.56 | 0.90 |
| **INVASIVE SHRUBS** | | | | | |
| 1 | *Lantana camara** | 1103.33 | 2.60 | 36.45 | 0.04 |
| 2 | *Rubus ellipticus** | 353.33 | 1.30 | 17.22 | 0.02 |
| 3 | *Rosa brunonii** | 313.33 | 0.59 | 12.56 | 0.02 |
| 4 | *Rubus niveus** | 213.33 | 0.80 | 10.02 | 0.05 |
| 5 | *Clematis gouriana** | 180.00 | 0.66 | 8.72 | 0.04 |
| 6 | *Reinwardtia indica** | 76.67 | 0.29 | 3.70 | 0.12 |
| 7 | *Pavetta indica** | 50.00 | 0.19 | 2.37 | 0.22 |
| 8 | *Urena lobata** | 13.33 | 0.06 | 0.67 | 1.20 |
| 9 | *Clematis Montana** | 10.00 | 0.05 | 0.53 | 0.90 |
| 10 | *Triumfetta rhomboidea** | 10.00 | 0.03 | 0.51 | 0.40 |
| 11 | *Solanum verbascifolium** | 6.67 | 0.04 | 0.37 | 2.40 |
| **SAPLINGS** | | | | | |
| 1 | *Euphorbia royleana** | 213.33 | 0.93 | 11.04 | 0.04 |
| 2 | *Rhus parviflora* | 250.00 | 0.82 | 10.91 | 0.05 |
| 3 | *Coculus laurifolius* | 116.67 | 0.20 | 4.91 | 0.05 |
| 4 | *Quercus leucotrichophora* | 93.33 | 0.31 | 4.09 | 0.13 |
| 5 | *Rhododendron arboreum* | 100.00 | 0.27 | 3.98 | 0.14 |
| 6 | *Myrica esculenta* | 66.67 | 0.31 | 3.48 | 0.14 |
| 7 | *Viburnum mullaha* | 66.67 | 0.20 | 3.22 | 0.08 |
| 8 | *Rhus cotinus* | 83.33 | 0.13 | 2.80 | 0.18 |
| 9 | *Viburnum cotinifolium* | 50.00 | 0.17 | 2.64 | 0.09 |
| 10 | *Indigofera pulchella* | 53.33 | 0.20 | 2.32 | 0.39 |
| 11 | *Coriaria nepalensis* | 36.67 | 0.14 | 1.82 | 0.21 |
| 12 | *Prunus cerasoides* | 30.00 | 0.15 | 1.70 | 0.22 |
| 13 | *Litsea glutinosa* | 40.00 | 0.11 | 1.63 | 0.29 |
| 14 | *Plumeria rubra* | 26.67 | 0.15 | 1.58 | 0.27 |
| 15 | *Cornus macrophylla* | 23.33 | 0.15 | 1.38 | 0.53 |
| 16 | *Ougeinia oojeinensis* | 33.33 | 0.07 | 1.33 | 0.24 |
| 17 | *Ficus arnottiana* | 26.67 | 0.07 | 1.24 | 0.20 |
| 18 | *Bauhinia variegate* | 16.67 | 0.09 | 1.02 | 0.38 |
| 19 | *Engelhardtia colebrookiana* | 16.67 | 0.09 | 1.00 | 0.38 |
| 20 | *Acer oblongum* | 16.67 | 0.08 | 0.94 | 0.38 |
| 21 | *Pinus roxburghii* | 20.00 | 0.07 | 0.94 | 0.45 |
| 22 | *Sageretia oppositifolia* | 20.00 | 0.06 | 0.89 | 0.45 |
| 23 | *Cotoneaster bacillaris* | 20.00 | 0.07 | 0.88 | 0.80 |
| 24 | *Lyonia ovalifolia* | 13.33 | 0.09 | 0.86 | 0.53 |
| 25 | *Ficus nemoralis* | 16.67 | 0.09 | 0.84 | 1.50 |
| 26 | *Cornus capitata* | 13.33 | 0.08 | 0.83 | 0.53 |
| 27 | *Bauhinia vahlii* | 13.33 | 0.06 | 0.79 | 0.30 |
| 28 | *Rhus wallichii* | 10.00 | 0.08 | 0.76 | 0.40 |
| 29 | *Pyrus pashia* | 13.33 | 0.05 | 0.61 | 1.20 |
| 30 | *Ficus auriculata* | 10.00 | 0.06 | 0.59 | 0.90 |
| 31 | *Bauhinia semla* | 13.33 | 0.02 | 0.52 | 0.53 |
| 32 | *Cinnamomum zylenica* | 6.67 | 0.03 | 0.34 | 2.40 |
| 33 | *Debregeasia velutina* | 6.67 | 0.01 | 0.22 | 2.40 |

## 1. Forest Invasive Species*

**Herb layer:** Under herbaceous layer two life forms of plants, i.e., herbs including invasive herbs and seedlings were recorded. Total 67 species were recorded in this layer. Out of these, 47 species were herbs and 20 species were in the form of seedlings of trees and shrubs (Table 3).

The most dominant species was *Eupatorium glandulosum* followed by *Oplismenus,* seedling of *Myrsine africana* and *Apluda mutica*.

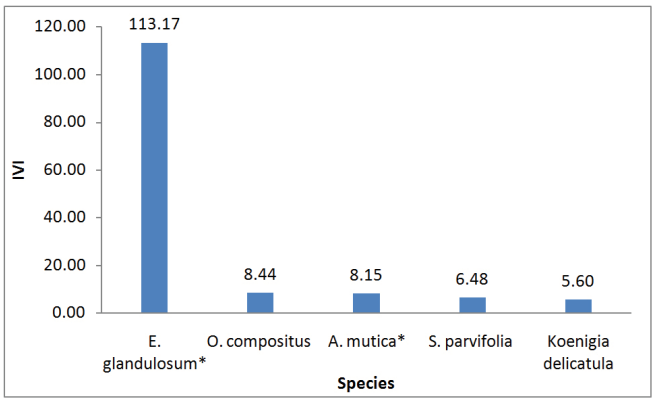


**Figure 4:** Dominant herbs of site I (Jardhar VFE).

**Invasion status of herb layer:** The most dominating invasive was *Eupatorium glandulosum* followed by *Apluda mutica, Anaphalis busua* and *Echinochloa colone.* A/F values reveal that invasives follows random as well as contiguous pattern. (Fig 4 & Table 3).

**Table 3: Vegetation composition of herb layer of site I (Jardhar VFE)**

| S. No. | Species | Den/ha | TBA ($m^2$/ha) | IVI | A/F |
|---|---|---|---|---|---|
| 1 | *Oplismenus compositus* | 9333.33 | 0.01 | 8.44 | 0.03 |
| 2 | *Smilax parvifolia* | 7250.00 | 0.01 | 6.48 | 0.04 |
| 3 | *Koenigia delicatula* | 5500.00 | 0.00 | 5.60 | 0.03 |
| 4 | *Aechmanthera tomentosa* | 6083.33 | 0.03 | 4.63 | 0.12 |
| 5 | *Bergenia ciliate* | 3333.33 | 0.01 | 3.28 | 0.06 |
| 6 | *Chrysopogon fulvus* | 2916.67 | 0.01 | 3.14 | 0.05 |
| 7 | *Viscum articulatum* | 2750.00 | 0.00 | 2.71 | 0.06 |
| 8 | *Persicaria capitata* | 2750.00 | 0.00 | 2.62 | 0.07 |
| 9 | *Bigonia picta* | 2750.00 | 0.00 | 2.58 | 0.08 |
| 10 | *Perilla frutescens* | 1666.67 | 0.00 | 1.74 | 0.09 |
| 11 | *Ischaenum angustifolium* | 1666.67 | 0.00 | 1.56 | 0.14 |
| 12 | *Arundinella nepalensis* | 1750.00 | 0.00 | 1.38 | 0.25 |
| 13 | *Elaeodendron glaucum* | 1250.00 | 0.01 | 1.22 | 0.18 |
| 14 | *Carum carvi* | 750.00 | 0.00 | 0.81 | 0.17 |
| 15 | *Withania somnifera* | 583.33 | 0.00 | 0.56 | 0.34 |
| **INVASIVE HERBS** | | | | | |
| 1 | *Eupatorium glandulosum** | 30333.33 | 7.18 | 113.17 | 0.03 |
| 2 | *Apluda mutica** | 12000.00 | 0.02 | 8.15 | 0.09 |
| 3 | *Anaphalis busua** | 5416.67 | 0.01 | 5.55 | 0.03 |
| 4 | *Nepeta graciliflora** | 6333.33 | 0.00 | 5.26 | 0.05 |
| 5 | *Echinochloa colona** | 4416.67 | 0.03 | 5.26 | 0.03 |
| 6 | *Cynodon dactylon** | 4833.33 | 0.00 | 4.66 | 0.04 |
| 7 | *Cymbopogon martinii** | 3833.33 | 0.01 | 4.20 | 0.03 |
| 8 | *Tridax procumbens** | 4500.00 | 0.01 | 4.09 | 0.06 |
| 9 | *Heteropogon contortus** | 3416.67 | 0.01 | 3.41 | 0.05 |
| 10 | *Parthenium hysterophrus** | 4250.00 | 0.01 | 3.38 | 0.13 |
| 11 | *Saccharum spontaneum** | 4083.33 | 0.00 | 3.25 | 0.10 |
| 12 | *Sonchus* sp.* | 3583.33 | 0.02 | 3.23 | 0.10 |
| 13 | *Euphorbia hirta** | 3000.00 | 0.01 | 3.15 | 0.05 |
| 14 | *Solanum nigrum** | 3416.67 | 0.02 | 2.90 | 0.14 |
| 15 | *Achyranthes aspera** | 2500.00 | 0.00 | 2.90 | 0.04 |
| 16 | *Ocimum basilicum** | 2916.67 | 0.00 | 2.83 | 0.07 |
| 17 | *Blainvillea acmella** | 3000.00 | 0.00 | 2.79 | 0.08 |
| 18 | *Rubia cordifolia** | 3500.00 | 0.01 | 2.63 | 0.17 |
| 19 | *Cuscuta reflexa** | 2250.00 | 0.01 | 2.50 | 0.06 |
| 20 | *Rumex hastatus** | 2750.00 | 0.00 | 2.30 | 0.12 |
| 21 | *Reinwardtia indica** | 2916.67 | 0.00 | 2.29 | 0.16 |
| 22 | *Senecio nudicaulis** | 1750.00 | 0.00 | 1.97 | 0.06 |
| 23 | *Argemone Mexicana** | 1583.33 | 0.01 | 1.95 | 0.07 |
| 24 | *Bupleurum hamiltonii** | 1916.67 | 0.00 | 1.74 | 0.12 |
| 25 | *Leucas lanata** | 2000.00 | 0.01 | 1.73 | 0.17 |
| 26 | *Delphinium denudatum** | 1583.33 | 0.00 | 1.70 | 0.09 |
| 27 | *Cyperus niveus** | 1333.33 | 0.00 | 1.46 | 0.10 |
| 28 | *Fimbristylis falcata** | 1250.00 | 0.00 | 1.33 | 0.11 |
| 29 | *Micromeria biflora** | 833.33 | 0.00 | 0.96 | 0.15 |
| 30 | *Fumaria indica** | 666.67 | 0.00 | 0.75 | 0.20 |
| 31 | *Cleome viscosa** | 416.67 | 0.00 | 0.51 | 0.24 |
| 32 | *Physalis peruviana** | 416.67 | 0.01 | 0.51 | 0.38 |
| **SEEDLINGS** | | | | | |
| 1 | *Myrsine africana* | 8000.00 | 0.02 | 8.22 | 0.02 |

| | | | | | |
|---|---|---|---|---|---|
| 2 | *Rubus ellipticus** | 3166.67 | 0.04 | 3.65 | 0.05 |
| 3 | *Murraya exotica* | 2916.67 | 0.01 | 3.22 | 0.05 |
| 4 | *Rosa brunonii** | 2500.00 | 0.02 | 2.80 | 0.06 |
| 5 | *Viburnum cotinifolium* | 2333.33 | 0.01 | 2.68 | 0.05 |
| 6 | *Asparagus adscendens* | 2833.33 | 0.00 | 2.63 | 0.08 |
| 7 | *Colebrookia oppositifolia* | 2666.67 | 0.01 | 2.51 | 0.10 |
| 8 | *Asparagus* sp. | 2083.33 | 0.01 | 2.47 | 0.05 |
| 9 | *Artemisia nilagarica* | 2166.67 | 0.01 | 2.34 | 0.07 |
| 10 | *Desmodium elegans* | 1833.33 | 0.01 | 2.11 | 0.07 |
| 11 | *Quercus leucotrichophora* | 1666.67 | 0.01 | 1.99 | 0.07 |
| 12 | *Indigofera pulchella* | 1583.33 | 0.01 | 1.92 | 0.06 |
| 13 | *Rhus cotinus* | 1666.67 | 0.01 | 1.84 | 0.08 |
| 14 | *Vitex negundo* | 1416.67 | 0.01 | 1.54 | 0.10 |
| 15 | *Litsea glutinosa* | 1250.00 | 0.01 | 1.43 | 0.11 |
| 16 | *Desmodium cephalotes* | 1333.33 | 0.00 | 1.40 | 0.11 |
| 17 | *Roylea calycina* | 1166.67 | 0.01 | 1.27 | 0.14 |
| 18 | *Berberis asiatica* | 1000.00 | 0.02 | 1.18 | 0.18 |
| 19 | *Cinnamomum tamala* | 1500.00 | 0.00 | 1.17 | 0.34 |
| 20 | *Rubus niveus** | 916.67 | 0.01 | 1.06 | 0.13 |

## 2. Forest Invasive Species*

ECOLOGICAL STATUS OF SITE II (KUTTHA VILLAGE FOREST ECOSYSTEM)

**Tree layer:** A total no of 36 tree species including a single invasive species *Euphorbia royleana* were recorded from tree stratum of the forest in different composition.

The most dominant species was *Pinus roxburghii* 2nd most dominating was *Rhus parviflora* followed by *Quercus leucotrichophora,* while *Euphorbia royleana* recorded as the 4th most dominating species (Fig 5 & Table 4).

In terms of invasion level, only single species *Euphorbia royleana* was found to be among tree layer. The species are contiguously distributed in the forest as shown by A/F values.

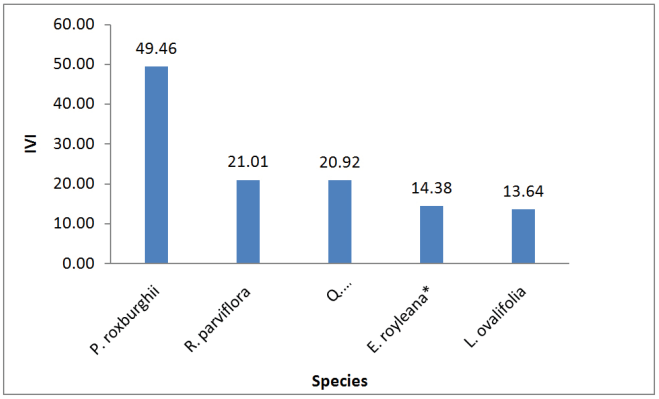


**Figure 5:** Dominant tree species of site II (Kuttha VFE)

**Table 4. Vegetation composition of tree layer of site II (Kuttha VFE)**

| S. No. | Species | Den/ ha | TBA m²/ha | IVI | A/F |
|---|---|---|---|---|---|
| 1 | *Pinus roxburghii* | 240 | 1.32 | 49.46 | 0.10 |
| 2 | *Rhus parviflora* | 74 | 0.16 | 21.01 | 0.06 |
| 3 | *Quercus leucotrichophora* | 52 | 0.33 | 20.92 | 0.36 |
| 4 | *Euphorbia royleana** | 52 | 0.12 | 14.38 | 0.16 |
| 5 | *Lyonia ovalifolia* | 36 | 0.17 | 13.64 | 0.11 |
| 6 | *Pyrus pashia* | 28 | 0.08 | 10.24 | 0.11 |
| 7 | *Sapium insigne* | 30 | 0.07 | 10.16 | 0.12 |
| 8 | *Lannea coromandelica* | 28 | 0.08 | 10.13 | 0.11 |
| 9 | *Ficus religiosa* | 8 | 0.06 | 8.47 | 0.50 |
| 10 | *Mallotus philippensis* | 24 | 0.05 | 8.25 | 0.17 |
| 11 | *Ficus auriculata* | 16 | 0.06 | 7.95 | 0.08 |
| 12 | *Grewia optiva* | 12 | 0.07 | 7.85 | 0.33 |
| 13 | *Prunus persica* | 8 | 0.05 | 7.63 | 0.50 |
| 14 | *Punica granatum* | 18 | 0.06 | 7.60 | 0.18 |
| 15 | *Toona ciliata* | 14 | 0.06 | 7.22 | 0.14 |
| 16 | *Ficus palmata* | 16 | 0.05 | 7.05 | 0.16 |
| 17 | *Woodfordia fruticosa* | 16 | 0.04 | 6.55 | 0.25 |
| 18 | *Prunus armeniaca* | 8 | 0.04 | 6.35 | 0.50 |
| 19 | *Engelhardtia colebrookiana* | 16 | 0.04 | 6.16 | 0.25 |
| 20 | *Cassia fistula* | 14 | 0.04 | 6.04 | 0.22 |
| 21 | *Prunus cerasoides* | 8 | 0.04 | 5.83 | 0.50 |
| 22 | *Nyctanthes arbortristis* | 8 | 0.03 | 5.41 | 0.50 |
| 23 | *Bauhinia variegata* | 12 | 0.03 | 5.41 | 0.33 |
| 24 | *Aegle marmelos* | 12 | 0.03 | 5.06 | 0.33 |

| | | | | | |
|---|---|---|---|---|---|
| 25 | *Debregeasia velutina* | 8 | 0.02 | 4.61 | 0.50 |
| 26 | *Emblica officinalis* | 4 | 0.02 | 4.13 | 1.00 |
| 27 | *Terminalia chebula* | 4 | 0.02 | 4.03 | 0.25 |
| 28 | *Ficus arnottiana* | 8 | 0.02 | 4.01 | 0.50 |
| 29 | *Vitex negundo* | 8 | 0.02 | 3.87 | 0.50 |
| 30 | *Melia azedarach* | 6 | 0.02 | 3.72 | 0.17 |
| 31 | *Erythrina suberosa* | 8 | 0.01 | 3.40 | 0.50 |
| 32 | *Indigofera pulchella* | 4 | 0.01 | 3.38 | 1.00 |
| 33 | *Thuja orientalis* | 6 | 0.01 | 2.78 | 0.38 |
| 34 | *Kydia calycina* | 2 | 0.01 | 2.66 | 0.50 |
| 35 | *Bauhinia vahlii* | 4 | 0.01 | 2.37 | 0.25 |
| 36 | *Flacourtia indica* | 4 | 0.01 | 2.28 | 1.00 |

Forest Invasive Species*

**Shrub layer:** The total species under shrub layer was recorded 39 in number (Table 5). Out of them 21 species were shrubs including invasives and 18 were tree species in the form of saplings. The most dominant species among shrubs was *Lantana camara* followed by sapling of *Rhus parviflora, Carissa opaca* and sapling *Euphorbia royleana*.

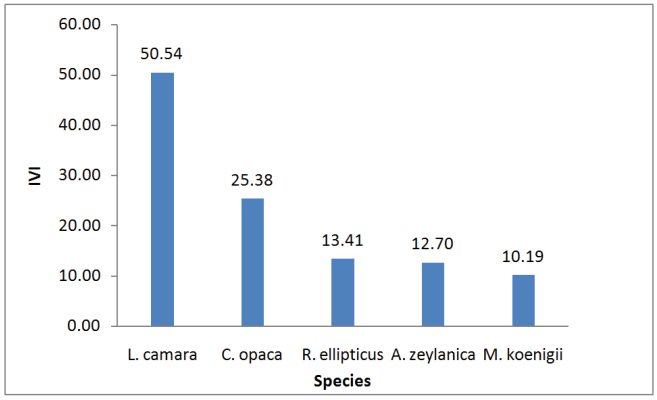


**Figure 6:** Dominant shrub species of site II (Kuttha VFE).

**Invasion status of shrub:** Shrub layer of Kuttha village forest ecosystem was invaded by 8 shrubby invasive species in different phytosociological attributes. Level of invasion was observed maximum for *Lantana camara* followed by saplings of *Euphorbia royleana,* and *Rubus ellipticus,* while the least dominating species was *Clematis gouriana* (Fig 6 & Table 5).

**Table 5:** Vegetation composition of shrub layer of site II (Kuttha VFE)

| S. No. | Species | Den/ha | TBA m²/ha | IVI | A/F |
|---|---|---|---|---|---|
| 1 | *Carissa opaca* | 440 | 1.28 | 25.38 | 0.07 |
| 2 | *Adhatoda zeylanica* | 304 | 0.69 | 12.70 | 0.53 |
| 3 | *Murraya koenigii* | 120 | 0.62 | 10.19 | 0.09 |
| 4 | *Agave cantula* | 128 | 0.73 | 10.04 | 0.16 |
| 5 | *Aegle marmelos* | 104 | 0.65 | 8.17 | 0.26 |
| 6 | *Caesalpinia decapetala* | 96 | 0.33 | 7.12 | 0.12 |
| 7 | *Roylea calycina* | 112 | 0.22 | 6.27 | 0.19 |
| 8 | *Woodfordia fruticosa* | 64 | 0.32 | 5.49 | 0.16 |
| 9 | *Berberis asiatica* | 96 | 0.17 | 4.75 | 0.38 |
| 10 | *Zanthoxylum armatum* | 40 | 0.16 | 3.12 | 0.28 |
| 11 | *Tephrosia candida* | 40 | 0.16 | 2.66 | 0.63 |
| 12 | *Cryptolepis buchanani* | 16 | 0.08 | 1.27 | 1.00 |
| 13 | *Gloriosa superba* | 16 | 0.03 | 0.97 | 1.00 |
| **INVASIVE SHRUBS** | | | | | |
| 1 | *Lantana camara** | 1256 | 2.84 | 50.54 | 0.18 |
| 2 | *Rubus ellipticus** | 264 | 0.62 | 13.41 | 0.17 |
| 3 | *Xanthium strumarium** | 168 | 0.69 | 10.07 | 0.29 |
| 4 | *Ricinus communis** | 88 | 0.30 | 6.31 | 0.15 |
| 5 | *Rosa brunonii** | 48 | 0.19 | 3.43 | 0.33 |
| 6 | *Reinwardtia indica** | 64 | 0.16 | 3.10 | 1.00 |
| 7 | *Datura metel** | 48 | 0.21 | 3.07 | 0.75 |
| 8 | *Clematis gouriana** | 24 | 0.13 | 2.19 | 0.38 |
| **SAPLINGS** | | | | | |
| 1 | *Rhus parviflora* | 688 | 2.31 | 37.58 | 0.08 |
| 2 | *Euphorbia royleana** | 344 | 1.63 | 21.27 | 0.18 |
| 3 | *Pinus roxburghii* | 136 | 0.72 | 11.54 | 0.09 |
| 4 | *Sapium insigne* | 112 | 0.36 | 7.12 | 0.19 |
| 5 | *Rhus cotinus* | 80 | 0.36 | 6.00 | 0.20 |
| 6 | *Ficus palmata* | 72 | 0.24 | 5.66 | 0.13 |
| 7 | *Grewia optiva* | 40 | 0.26 | 3.70 | 0.28 |
| 8 | *Vitex negundo* | 48 | 0.14 | 3.62 | 0.19 |
| 9 | *Punica granatum* | 40 | 0.20 | 3.36 | 0.28 |
| 10 | *Indigofera pulchella* | 16 | 0.04 | 1.51 | 0.25 |
| 11 | *Lannea coromandelica* | 24 | 0.06 | 1.26 | 1.50 |
| 12 | *Mallotus philippensis* | 16 | 0.08 | 1.24 | 1.00 |
| 13 | *Erythrina suberosa* | 16 | 0.07 | 1.21 | 1.00 |

| | | | | | |
|---|---|---|---|---|---|
| 14 | *Quercus leucotrichophora* | 16 | 0.07 | 1.18 | 1.00 |
| 15 | *Engelhardtia colebrookiana* | 16 | 0.05 | 1.07 | 1.00 |
| 16 | *Flacourtia indica* | 16 | 0.03 | 0.98 | 1.00 |
| 17 | *Bauhinia vahlii* | 8 | 0.02 | 0.76 | 0.50 |
| 18 | *Ficus arnottiana* | 8 | 0.02 | 0.72 | 0.50 |

Forest Invasive Species*

**Herb layer:** In the site study a total no. of 51 species were recorded under herb layer (**Table 6)** among them 11 no. of species were counted as seedlings of trees and shrubs whereas 40 were of herbaceous species including invasives. The most dominating herb was *Eupatorium glandulosum* co-dominated by *Parthenium hysterophorus* followed by seedling of native species *Rhus parviflora.*

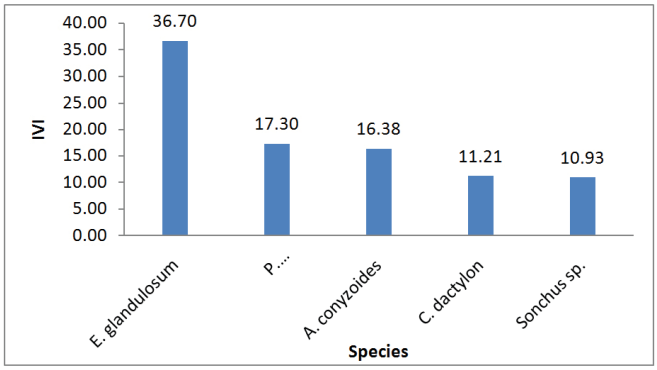


**Figure 7:** Dominat herb species of site II (Kuttha VFE).

**Invasion status of herb layer:** A total no. of 34 herbaceous invasive species was recorded from the forest (**Table 6).** The most noxious species was *Eupatorium glandulosum* followed by *Parthenium hysterophorus* and *Ageratum conyzoides* in herb layer.

These species are distributed in contiguous pattern in the herb layer.

**Table 6: Vegetation composition of herb layer of site II (Kuttha VFE)**

| S. No. | Species | Den/ ha | TBA $m^2$/ha | IVI | A/F |
|---|---|---|---|---|---|
| 1 | *Oplismenus compositus* | 4800 | 0.10 | 8.27 | 0.48 |
| 2 | *Echinops echinatus* | 1800 | 0.05 | 4.03 | 0.50 |
| 3 | *Ischaemum angustifolium* | 2000 | 0.07 | 3.73 | 1.25 |
| 4 | *Cajanus volubilis* | 1400 | 0.05 | 2.98 | 0.88 |
| 5 | *Bigonia picta* | 600 | 0.03 | 1.45 | 1.50 |
| 6 | *Bergenia ciliata* | 600 | 0.02 | 1.41 | 1.50 |
| | INVASIVE HERBS | | | | |
| 1 | *Eupatorium glandulosum** | 12000 | 2.06 | 36.70 | 0.37 |
| 2 | *Parthenium hysterophorus** | 7600 | 0.77 | 17.30 | 0.76 |
| 3 | *Ageratum conyzoides** | 9800 | 0.37 | 16.38 | 0.50 |
| 4 | *Cynodon dactylon** | 7000 | 0.21 | 11.21 | 0.70 |
| 5 | *Sonchus sp.** | 3400 | 0.47 | 10.93 | 0.34 |
| 6 | *Oxalis dehradunensis** | 5600 | 0.24 | 9.66 | 0.88 |
| 7 | *Sonchus* sp* | 3600 | 0.33 | 9.00 | 0.56 |
| 8 | *Rumex hastatus** | 3400 | 0.25 | 8.67 | 0.34 |
| 9 | *Oxalis corniculata** | 4400 | 0.11 | 7.34 | 0.69 |
| 10 | *Syndrella* sp* | 3800 | 0.15 | 7.27 | 0.59 |
| 11 | *Bidens pilosa** | 2800 | 0.14 | 7.08 | 0.28 |
| 12 | *Saccharum spontaneum** | 4000 | 0.09 | 6.87 | 0.63 |
| 13 | *Nicotiana plumbaginifolia** | 1800 | 0.21 | 5.60 | 0.50 |
| 14 | *Boerhavia diffusa** | 2000 | 0.14 | 5.12 | 0.56 |
| 15 | *Achyranthes aspera** | 2200 | 0.12 | 5.02 | 0.61 |
| 16 | *Tridax procumbens** | 2400 | 0.07 | 4.72 | 0.67 |
| 17 | *Sedum multicaule** | 2000 | 0.10 | 3.94 | 1.25 |
| 18 | *Stellaria media** | 2200 | 0.08 | 3.92 | 1.38 |
| 19 | *Polygonum plebeium** | 1600 | 0.11 | 3.78 | 1.00 |
| 20 | *Argemone mexicana** | 1400 | 0.13 | 3.78 | 0.88 |
| 21 | *Euphorbia hirta** | 2000 | 0.08 | 3.75 | 1.25 |
| 22 | *Commelina benghalensis** | 2200 | 0.04 | 3.56 | 1.38 |
| 23 | *Solanum nigrum** | 1000 | 0.13 | 3.54 | 0.63 |
| 24 | *Apluda mutica** | 1800 | 0.06 | 3.42 | 1.13 |
| 25 | *Senecio nudicaulis** | 1200 | 0.06 | 2.92 | 0.75 |
| 26 | *Rubia cordifolia** | 1200 | 0.06 | 2.91 | 0.75 |
| 27 | *Desmodium triflorum** | 1200 | 0.05 | 2.83 | 0.75 |
| 28 | *Anaphalis busua** | 1200 | 0.04 | 2.02 | 3.00 |
| 29 | *Origanum vulgare** | 600 | 0.07 | 1.91 | 1.50 |
| 30 | *Kyllinga brevifolia** | 800 | 0.04 | 1.76 | 2.00 |
| 31 | *Sida rhombifolia** | 600 | 0.05 | 1.65 | 1.50 |
| 32 | *Reinwardtia indica** | 400 | 0.04 | 1.41 | 1.00 |
| 33 | *Amaranthus spinosus** | 400 | 0.02 | 1.26 | 1.00 |
| 34 | *Rorippa indica** | 400 | 0.02 | 1.21 | 1.00 |
| | SEEDLINGS | | | | |
| 1 | *Rhus parviflora* | 4600 | 0.66 | 15.88 | 0.18 |
| 2 | *Xanthium strumarium** | 3800 | 0.54 | 11.29 | 0.59 |
| 3 | *Carissa opaca* | 1400 | 0.25 | 5.70 | 0.39 |
| 4 | *Agave cantula* | 800 | 0.25 | 4.56 | 0.50 |
| 5 | *Pinus roxburghii* | 1200 | 0.18 | 4.20 | 0.75 |
| 6 | *Desmodium cephalotes* | 1000 | 0.16 | 3.80 | 0.63 |
| 7 | *Lantana camara** | 1000 | 0.15 | 3.70 | 0.63 |

| | | | | | |
|---|---|---|---|---|---|
| 8 | *Roylea calycina* | 1200 | 0.10 | 3.32 | 0.75 |
| 9 | *Rubus ellipticus** | 400 | 0.18 | 2.87 | 1.00 |
| 10 | *Datura metel** | 800 | 0.09 | 2.27 | 2.00 |
| 11 | *Berberis asiatica* | 400 | 0.11 | 2.10 | 1.00 |

Forest Invasive Species*

## DISCUSSION

Many plant species serve as indicators of ecological conditions and have been used for site evaluation (Rowe, 1956).

The present study was conducted in two different sites. i.e. Jardhar villege forest and Kuttha village forest. The study reveals that both the sites are invaded by Forest Invasive Species in all the layers of the forest ecosystem. The level of invasion in terms of their dominance, density and basal cover varies as per site conditions. As in Jardhar village forest, *Quercus leucotrichophora*, *Rhododendron arboreum*, *Pinus roxburghii* etc. were the dominant trees, whereas, the Kuttha village forest is occupied by *Pinus roxburghii, Rhus parviflora*, *Quercus leucotrichophora* etc, also invaded by *Euphorbia royleana.* It indicates that both the forest types are infested by invasives but the level of infestation is high in *Pinus roxburghii* dominated site. *Pinus roxburghii* is the pioneer species in low soil depth and nutrients deficient degraded slopes These soil conditions provokes the growth of *Euphorbia royleana,* as also suggested by other workers (Munesh K *et.al.,* 2017, Adhikari *et.al.,* 2009, Banerjee, 1986). *Euphorbia royleana* infestation was also reported from *Quercus leucotrichophora* dominated site but its expansion was reported from the eroded and degraded rocky pockets of the forest. But was less as compare to the *Pinus roxburghii* dominated sites, as shown in the study Table 1&4.

In shrub layer, the dominance of *Lantana camara,* a shrubby invasive in both the sites has resulted in the replacement of native species of the region (Love *et. al., 2009*). Thus native species are now being treated as secondary species. Spreading foliage of *Lantana camara,* which are making impenetrable thickets, covers the ground fully and promoting shade condition, which prepare the ground for the shade or moisture loving species. The tendency of this invasive though sometimes favours the shade and moist loving native species but such areas are found to be encroached by shade loving invasive *Eupatorium glandulosum*, as its dominance in herbaceous layer suggest this fact; therefore it is presumed that dominance of *Lantana camara* in shrub layer indirectly making the encroached area more prone for further invasion (Lau 2008, Holzmueller and Jose, 2009, Usher 1991), and the infestation in phytosociological terms was recorded high in *Pinus roxburghii* dominated site as the site is more prone (Uniyal 1995) .

Researcher observed that some plants such as *Lantana camara* and *Euphorbia royleana* altogether occupying and multiplying rapidly in dry, eroded and disturbed localities (especially Kuttha village forest ecosystem). These species are reducing the native vegetation of these slopes as the same have been reported by (Banerjee, 1989). Similarly *Eupatorium glandulosum, Parthenium hysterophorus* and *Ageratum conyzoides* are quickly moving towards the inner ranges of the forest as revealed from phytosociological analysis of area and the same have also been reported from district Uttarkashi and Pauri Garhwal by Gaur (1999), thus presumed that the natives of these encroached elevation certainly get displace due to current exisistence and dominance of forest invasive species.

Silvicultural practices (Troup, 1921) reveals that the nature of the maximum natives (trees, shrubs and herbs, except *Pinus roxburghii*) and invasive *Eupatorium glandulosum, Rosa brunonii, Clematis gouriana,* etc. are moisture loving whereas invasive *Lantana camara, Euphorbia royleana* grow well in all kind of conditions (Howard, 1969; Banerjee, 1989), thus all moist pockets of the forest where native species could recruit (especially as in Jardhar village forest) are encroached by these invasives, and by virtue of specific traits and characteristic features (Reddy *et. al.,* 2002; Love *et al.,* 2009) these species became good competitor over native species, therefore natives though recruit but least in dominance as found to be replaced by invasive shrubs and herbs hence creating loss of native biodiversity as also studied by *Sharma et al.,* 2005a; Day *et al.,* 2003; Webster *et al.,* 2006). (Table 1 to 6 and Fig. 2 to 7).

## CONCLUSION

The study indicates that site, which is *Pinus roxburghii* dominated, is under threat and more prone to further invasion as compared to the *Quercus leucotrichophora* dominated site. High level of invasion in the shrub and herb layer imply towards the immerging threat to native biodiversity of the study area. Therefore, there is an urgent need to check, monitor, and evaluate the further invasion and needs to apply the scientific corrective measures.

## ACKNOWLEDGMENT

Authors are grateful to the Forest Research Institute, Dehradun. We acknowledge the immense help received from the scholars whose articles are cited and included in references of this manuscript. The authors are also grateful to authors/editors/publishers of all those articles, journals and books from where the literature for this article has been reviewed and discussed.

## REFERENCES


1. Adhikari BS, Uniyal SK, Rawat GS. Vegetation structure and community patterns of Tehri Dam Submergence Zone, Uttarakhand, India. *EurAsia J BioSci* 2009; 3, 40-49.
2. Banerjee A K. Shrubs in tropical forest ecosystem example from India. 1989. In: *World Bank Technical Paper Number 103*. The World Bank, Washington, DC, U.S.A.
3. Chaudhry P, Dollo M, Bagra K, Yakang B. Traditional biodiversity conservation and natural resource management system of some tribes of Arunanchal Pradesh. *Interdisciplinary Environmental Review.* 2011; 12(4):338-348.
4. Curtis JT, Cottam G. Plant Ecology Work Book. 1956; *A Laboratory Field Reference Manual*. Minnesota, Burgess Publishing CO., 193.
5. Curtis JT, McIntosh RP. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology,* 1950; 31:434-455.
6. Day M, Wiley CJ, Playford J, Zalucki MP. *Lantana*: current management status and future prospects. *ACIAR Monograph*, 2003; 102, 28.
7. Gaur RD. Flora of the District Garhwal North West Himalaya (with etnobotanical notes). 1999. Transmedia, Srinagar Garhwal, India.
8. Holzmueller EJ, Jose S. Invasive plant conundrum: What makes the aliens so successful. *Journal of Tropical agriculture,* 2009; 47(1-2):18-29.
9. Howard RA. A checklist of cultivar names used in the genus *Lantana. Arnoldia.* 1969; 29: 73-109.
10. Kent M, Coker P. *Vegetation Description and Analysis, A Practical Approach.* Belhaven Press1992, London.
11. Knight DH. A distance method for construction of forest profile diagrams and obtaining structural data. *Trop. Ecol.* 1963; 4: 89-94.
12. Kumar M, Kumar S, Sheikh MA. Effect of altitudes on soil and vegetation characterstics of Pinus roxburghii forest in Garhwal Himalaya. Journal of Advanced Laboratory Research in Biology, 2017; 1(2):130-133.
13. Lau JA. Beyond the ecological: Biological invasions alter natural selection on a native plant species. *Ecology,* 2008; 89(4):1023-1031.
14. Lindenmayer DB, Franklin JF. Forest structure and sustainable temperate forestry: A case study from Australia. *Conserv. Biol.*1997; 11: 1053-1068.
15. Love A, Babu S, Babu CR. Management of *Lantana*, an invasive alien weed, in forest ecosystems of India. *Curr. Sci.,* 2009; 97(10) 1421-1429.
16. McNeely JA, Mooney HA, Neville LE, Schei P, Waage JK, editors. A Global strategy on Invasive Alien Species. IUCN Gland, Switzerland, and Cambridge, UK. 2001; 1-62.
17. Mishra R. Ecology Work Book. Oxford and IBS Publishing Company, Calcutta. 1968.
18. Mooney HA, Drake JA. The ecology of biological invasions. *Environment.* 1987; 29(5):12.
19. Mueller-Dombois D, Ellenberg H. *Aims and Methods of Vegetation Ecology*. John Willey and Sons 1974., New York.
20. Phillips EA. Methods of Vegetation Study. Henry Holt & Company.1959; New York.
21. Raizada P, Sharma GP, Raghubanshi AS. Ingress of Lantana in dry tropical forest fragmrents: Edge and shade effects. *Curr Sci.*2008; 94(2):180-182.
22. Rana JC, Singh A, Sharma Y, Pradheep K, Mendiratta N. Dynamics of plant bioresources in western Himalayan region of India- watershed based study. *Curr. Sci.* 2010; 98 (2): 192-203.
23. Reddy S, Bagyanarayana G, Reddy KN, Raju VS. *Invasive Alien Flora of India.* National Biological Information Infrastructure. 2002; USGS, USA.
24. Rowe J. Uses of undergrowth plant species in forestry. *Ecol.* 1956; 37:461-473.
25. Sharma GP, Singh JS, Raghubanshi AS. Plant Invasion: emerging trends and future implications. *Curr. Sci.,* 2005a.; 88. 726-734.
26. Troup RS. Silviculture of Indian Trees. Vol II. Clarendon press. Oxford. 1921.
27. Uniyal BP, Singh S, Singh DK. Plant Diversity in the Tehri Dam Submersible Area. Botanical Survey of India, Govt. India. 1995.
28. Usher M. Biological invasions into tropical nature reserves. Ed: Ramakrishnan PS. Ecology of Biological invasion in the Tropics, 1991; 21-34.
29. Webster CR, Jenkins MA, Jose S. Woody invaders and the challenges they pose to forest ecosystems in the eastern United States, *J. Forestry.* 2006; 104,366.
30. Whitford PB. Distribution of woodland plants in relation to successional and clonal growth. *Ecology.* 1949; 30:199-208.